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IMPROVED SYNTHESIS OF 2-DEOXY-L-RIBOSE

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ABSTRACT: Improved synthesis of 2-deoxy-L-ribose and the corresponding 2-deoxy-3,5-di-*O*-*p*-toluoyl-α-L-*erythro*-pentofuranosyl chloride are described from L-arabinose.

Modification of carbohydrate provides a variety of sugar derivatives for the synthesis of new nucleosides and nucleotides. Recently, the number of reports of L-nucleosides as antiviral agents has increased dramatically due to their potent biological activity and lower toxicity compared to their counterpart D-nucleosides.[1-6] The most active L-nucleosides include L-thymidine (L-T),[2] L-3'-thiacytidine (3TC),[3] L-5-fluoro-3'-thiacytidine (FTC),[3a,4] L-2',3'-dideoxycytidine (L-ddC),[5] L-5-fluoro-2',3'-dideoxycytidine (L-FddC),[5b,5c] and L-FMAU.[6] However, the high cost of L-ribose and 2-deoxy-L-ribose hampered their use as starting material for the synthesis of L-nucleosides in large quantities. Therefore, new and improved syntheses of 2-deoxy-L-ribose and L-ribose are of considerable interest.

Several syntheses of 2-deoxy-L-ribose are known in the literature.[7-10] Most of them use L-arabinose[7] or L-ribose[7c] or L-ascorbic acid[8] as the starting materials. A few others led to 2-deoxy-L-ribose from achiral precursors.[9,10] However, none of these methods have been applied to large scale synthesis of 2-deoxy-L-ribose. Our interest in 2'-deoxy-L-nucleosides and their biological activities led us to seek an economical and efficient procedure for the preparation of 2-deoxy-L-ribose in large quantities. Among the available methods in the literature for the synthesis of 2-deoxy-L-ribose, we chose one[7b] that starts with L-arabinose. However, after following this procedure we came across a couple of problems that have not been addressed in the original paper.[7b]

Herein, we report an improved procedure, in particular, with the key deoxygenation step, to enhance reproducibility and suitability for large scale preparation.

The improved synthesis of 2-deoxy-L-ribofuranose is illustrated in Scheme 1. L-Arabinose was heated at reflux in methanol containing catalytic amount of conc. HCl for 2 h. The resulting solution upon concentration and cooling afforded methyl β-L-arabinopyranose in 81% yield.[11] Reaction of 2 with dimethoxypropane in dry DMF and Amberlyst 15 (H^+ form) resin for 18 h gave the methyl 3,4-*O*-isopropylidene-β-L-arabinose (**3**). Intermediate **3** was reacted with NaH then with carbon disulfide and methyl iodide at 0°C to afford the corresponding methyl 3,4-*O*-isopropylidene-2-*O*-[(methylthio)thiocarbonyl]-β-L-arabinopyranose (**4**).[7b] Compound **4** was dissolved in dry xylene, degassed and treated with tri-n-butyltin hydride and AIBN under argon atmosphere for 3 h as described in the literature.[7b] The volatile matters were evaporated and the residue was treated with 80% AcOH for 15 h. The reaction mixture was worked up as described in the literature[7b] and analyzed by tlc, which showed two major products and one minor product. The separation of the product from the byproducts was found to be tedious and cumbersome. In order to identify the byproducts, we repeated the deoxygenation of **4** with tri-n-butyltin hydride and AIBN as above. The reaction was then checked by tlc before treating with 80% AcOH, which revealed the existence of two products. The reaction mixture was evaporated and purified by flash chromatography without exposing the mixture to 80% AcOH. The fast moving product was isolated in 55% yield and the slow moving product accounted for 30%.

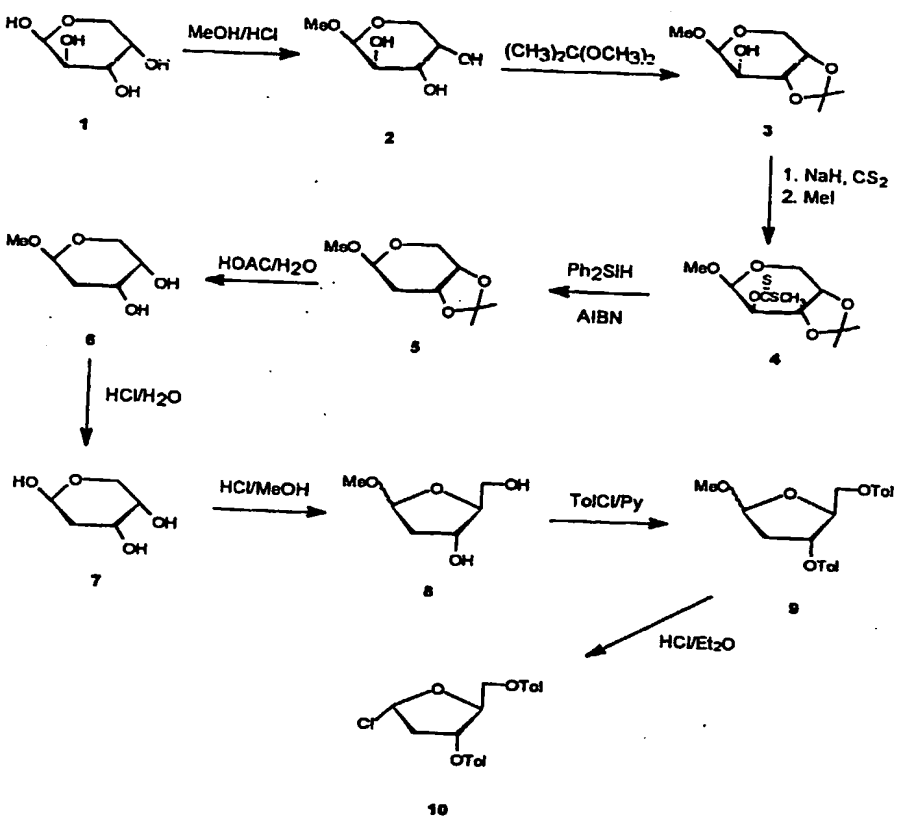
^{1}H NMR analysis of the fast moving product confirmed this was **5**. The ^{1}H NMR of the slow moving product indicated the presence of a hydroxyl group at δ 2.43, isopropylidene functionality (δ 1.53 & 1.36) and methyl ether protons (δ 3.44). Furthermore, the NMR spectrum of the slow moving product was identical to that of **3**. Thus, we assigned the structure of the slow moving product as **3**. We believe that the formation of **3**, in addition to **5**, was the result of nucleophilic attack on 2'-*O*-(methylthio)thiocarbonyl group of **4** by tri-*n*-butyltin hydride, probably due to the increased electrophilicity of the thiocarbonyl group when chelated with tin ion. Attempts to eliminate the formation of **3**, by reducing the reaction temperature, changing the solvent and using fresh tri-*n*-butyltin hydride were fruitless. During the deoxygenation of **4**, the crude mixture of products was reacted directly with 80%

OH, resulting in a mixture of **2** and **6**. These species could not be separated on silica l column. Therefore, the problem associated with deoxygenation of **4** with tri-*n*-tyltin hydride made the reported procedure[7b] unsuitable for large scale work and an ernative deoxygenation procedure for compound **4** was sought.

After survey of available methods for deoxygenation, we decided to use henylsilane[12] based on its performance and lack of nucleophilicity. As we ticipated, refluxing a mixture of **4** and diphenylsilane in the presence of AIBN in dry oxane for 18 h under argon atmosphere gave exclusively **5**, which on exposure to 80% OH gave **6** in 81% yield. However, when the same reaction was carried out in other lvents, it did not go to completion, even with excess AIBN and diphenylsilane. The gnificance of the modified procedure is twofold. First, the expected product **5** was rmed cleanly. Secondly, the formation of obnoxious smelly tributyltin-ethylthiomercaptan complex byproduct in the tri-*n*-butyltin hydride method was oided thus making the improved procedure environmentally acceptable. Furthermore, e reaction can be scaled up to kilogram quantities without complication.

Following the reported[7b] procedure **6** was converted into 2-deoxy-L-ribose (**7**) in 1% yield. Treatment of **7** with 1% HCl/MeOH as described in the literature[7b] for 2 h ovided three products out of which the pyranose-form (six-member ring) of (**8**) was und to be the major product. The formation of the unwanted pyranose-form made us modify the condition for the transformation of **7** into **8**. After several attempts we tablished a reproducible method for the conversion of **7** to **8**. Thus, exposure of a ethanolic solution of **7** to 1% HCl/MeOH for 1 h followed by immediate quenching of e reaction with pyridine and purification afforded **8** as an α,β- mixtures in 80% yield. tirring of **8** with toluoyl chloride in pyridine provided the corresponding α,β- mixture f ditoluoyl derivatives **9** which on treatment with dry HCl gas in ether at 0°C afforded e required 2-deoxy-3,5-di-*O*-*p*-toluoyl-α-*erythro*-pentofuranosyl chloride (**10**)[13] in ood yield (92%).

In conclusion, we have modified and improved a commonly used reported rocedure to provide 2-deoxy-L-ribose and the corresponding 2-deoxy-3,5-di-*O*-*p*-oluoyl-α-L-*erythro*-pentofuranosyl chloride in higher yield from L-arabinose, which an be readily adapted to large scale preparation.



Scheme 1

Experimental

Melting points were taken on a Haake Buchler capillary melting point apparatus and are uncorrected. Nuclear magnetic resonance (^{1}H NMR) spectra were recorded on Varian mercury 300Hz spectrometer. The chemical shifts are expressed in δ values (ppm) relative to TMS as internal standard. Thin layer chromatography (TLC) was performed on plates of silica gel 60F_{254} coated on aluminum sheets (5x10 cm; EM Science) using different solvents prepared freshly. ICN silica gel 18-32 (60 A) was used for flash column chromatography. All solvents used were reagent grade. Most of the dry solvents were purchased from Fluka and used as such without further purification. Most of the reactions were conducted under argon atmosphere. Evaporations were carried out under reduced pressure with the bath temperature below 35°C.

Methyl β-L-arabinoside (2). To a suspension of L-arabinose (100 g, 667 mmol) anhydrous MeOH (450 mL) was added a HCl /MeOH solution (7.3 g dry HCl in 50 L MeOH) at room temperature under argon atmosphere. The mixture was refluxed r 2 h and cooled down to room temperature. The solution was concentrated to about 4 of its volume to give a suspension. The solid precipitated was filtered and washed ith cold MeOH (20 mL) to give the first crop as a crystalline powder (40.23 g). The ltrate was concentrated (35°C) to 1/4 of its volume. The solid precipitated was ltered, washed and dried as above to give the second crop (14.66 g) as a colorless ystalline powder. The concentration and filtration were repeated to afford additional 3.61 g of the product (total 88.5 g, 81 %). Mp 162-164°C. ^{1}H NMR (D_2O) δ 3.30 (s, H, OCH_3), 3.56 (dd, 1H, H_5), 3.73 (m, 1H, H_4), 3.77 (dd, 1H, H_5), 3.82 (bs, 1H, H_2), .73 (m, 1H, H_1).

Methyl 3,4-*O*-isopropylidene-β-L-arabinoside (3). To the mixture of methyl β--arabinoside **2** (23.33 g, 142.26 mmol) and dimethoxypropane (55 mL, 448 mmol) in ry DMF (185 mL) was added Amberlyst 15 (H^+ form, 1.42 g) and the suspension was tirred at room temperature for 18 h. The resin was filtered and the filtrate was vaporated to a syrup, which was dissolved in EtOAc (200 mL). This solution was vashed with brine (50 mL), sat. $NaHCO_3$ solution and brine (20 mL). The aqueous vashings were combined and extracted with EtOAc (5 x 20 mL), which was washed vith brine and combined with the organic solution. The organic extract was dried (anh-drous Na_2SO_4) and evaporated to dryness to give a syrup (29.2 g, quant.). ^{1}H NMR $CDCl_3$) δ 1.36, 1.53 (2s, 6H, isopropylidene-CH_3), 2.43 (d, 1H, 2'-O*H*), 3.44 (s, 3H,)CH_3), 3.78 (m, 1H, H_2), 3.93 (s, 2H, H_5), 4.15-4.25 (m, 2H, H_3,H_4), 4.71 (d, 1H, H_1).

Methyl 3,4-*O*-isopropylidene-2-*O*-[(methylthio)thiocarbonyl]-β-L-arabino-ide (4). The above syrup **3** (29.2 g, 142.26 mmol) was dissolved in anhydrous THF 190 mL) and cooled to 0°C. To the solution was added NaH (55-65%, 6.9 g, 172.5 nmol) slowly under argon atmosphere. The suspension was refluxed for 2 h and cooled o 0°C. To the mixture was added carbon disulfide (21 mL, 349.14 mmol) and the esultant dark mixture were stirred at room temperature for 2 h. To the mixture was dded methyl iodide (12.4 mL, 160.64 mmol) at 0°C and the mixture were stirred for 16 h. The mixture was poured into ice water (300 mL) and extracted with EtOAc (3 x 50 mL). The EtOAc solution was dried and evaporated until crystals precipitated. The

suspension was left in a refrigerator for 16 h. The crystals were filtered and washed with hexane to give the first crop (21.61 g) as a yellowish powder. The filtrate was concentrated, kept at 0°C overnight and filtered to give the second crop (16.51 g). This was repeated two more times to give additional 1.44 g of the product (39.62 g, two steps from 2 95%). Mp 127-130°C (lit.[7b] 127-130°C). ^{1}H NMR ($CDCl_3$) δ 1.39 and 1.55 (2s, 6H, isopropylidene-CH_3), 2.60 (s, 3H, SCH_3,), 3.40 (s, 3H, OCH_3), 4.01 (s, 2H, H_5), 4.30 (m, 1H, H_4), 4.50 (dd, 1H, H_3), 4.98 (d, 1H, H_1), 5.78 (dd, 1H, H_2).

Methyl -deoxy-β-L-*erythro*-pentopyranoside (6). Compound 4 (40 g, 136 mmol) and AIBN (24.6 g, 150 mmol) were dissolved in dry dioxane (400 mL) by heating in an oil bath (100°C). The mixture was bubbled with argon at 100°C for 15 min and then diphenylsilane (51.4 mL, 272 mmol) was added. The temperature of the oil bath was raised to 130°C and the mixture was refluxed for 12 h. Additional diphenylsilane (2 mL, 10.8 mmol) and AIBN (1.27 g, 7.7 mmol) were added and refluxing was continued for additional 5 h. The mixture was cooled and evaporated to give 5 as a syrup, which was mixed with 80% HOAc (544 mL) and stirred at room temperature for 16 h. The mixture was concentrated to half of its original volume and partitioned between water and ether. The aqueous layer was washed with ether and the combined organic layer was extracted with water. The aqueous solution was evaporated to give compound 6 as a syrup (lit.[7b] 75-78°C, 16.36 g, 81% for two steps from 4). ^{1}H NMR ($CDCl_3$) δ), 1.89 (dd, 2H, H_2). 2.30 (d,1H, OH), 2.47 (d, 1H, OH), 3.35 (s, 3H, OCH_3,), 3.88-3.69 (m, 3H, H_4 & H_5), 4.03 (m, 1H, H_3), 4.79 (t, 1H, H_1).

2-Deoxy-β-L-*erythro*-pentofuranose (7). Compound 6 (16.36 g, 110.5 mmol) was dissolved in 0.8 M HCl aqueous solution (546 mL) and the resultant mixture was stirred at room temperature for 72 h. The mixture was neutralized with aqueous NaOH (1M) to pH 6-7 and was evaporated to give syrup. The crude material was purified on a silica gel column (4 x 15 cm) eluted with CH_2Cl_2/MeOH (1:0 to 95:5) The proper fractions were evaporated to give compound 7 as syrup (10.53 g, 71.1%).

Methyl 2-deoxy-β-L-*erythro*-pentofuranose (8). Compound 7 (15.68 g, 117.0 mmol) was dissolved in dry MeOH (342 mL) and to the resultant solution was added 1 % HCl/MeOH (35 mL). The solution was kept at room temperature for 1 h and neutralized with Py (55 mL) at 5°C to pH ~ 6. The mixture was evaporated with silica gel and purified on a silica gel column (1 x 5 cm) eluted with CH_2Cl_2/MeOH (98:2 to

:4) to give compound **8** as a syrup (13.94 g, 81%). ^{1}H NMR ($CDCl_3$) δ 2.22-2.44 (m, I, H_2), 3.50 and 3.59 (2s, 3H, OCH_3), 3.75-3.88 (m, 2H, H_5), 4.26 (m, 1H, H_4), 4.66 ι, 1H, H_3), 5.25 (t, 1H, H_1).

Methyl 2-deoxy-3, 5-di-*O*-*p*-toluoyl-L-*erythro*-pentofuranose (9). Compound (9.00 g, 60.8 mmol) was dissolved in pyridine (180 mL) and cooled in an ice-water th. To this cold solution was added *p*-toluoyl chloride (18 mL, 136.00 mmol) over) min and the resultant solution was stirred at room temperature for 16 h. The mixture as evaporated to dryness. The residue was extracted with EtOAc and the extract ashed with brine, dried and evaporated. The crude product was purified on a silica gel)lumn (3 x 15 cm) using hexane/EtOAc (1:0 to 5:1) as the eluent. Evaporation of the oper fractions gave compound **9** as syrup (22.63g, 97%). ^{1}H NMR ($CDCl_3$) δ 2.40 :s, 6H, 2xCH_3), 3.35 (s, 3H, OCH_3-β), 3.41 (s, 3H, OCH_3-α), 4.6-4.5 (m, H_4 and H_5 of)th anomers), 5.19 (d, 1H, H_1-α), 5.21 (dd, 1H, H_1-β), 5.41 (m, 1H, H_3-α), 5.59 (m, H, H_3-β), 7.18-8.02 (m, 8H, aromatic).

2-Deoxy-3,5-di-*O*-*p*-toluoyl-α-L-*erythro*-pentofuranosyl chloride (10). ompound **9** (22 g, 57.3 mmol) was dissolved in dry ether (200 mL) and the solution ras cooled to 0°C in an ice bath. To the solution was bubbled dry HCl for ~ 5 min until ıe mixture crystallized. The reaction mixture was then kept in a refrigerator overnight. 'he solid that precipitated was filtered and washed with cold ether. The solid was nmediately dried under vacuum over NaOH to give compound **10** as a colorless rystalline powder (19.28 g). The filtrate was concentrated and treated with HCl and ept in a refrigerator overnight. Filtration, washing and drying gave additional 1.2 g of roduct (total 20.48 g, 92%); mp 118-121°C (lit.[7b,13] 118 –120°C). ^{1}H NMR ($CDCl_3$) δ :.39 (2s, 6H, aromatic-CH_3), 2.82 (m, 2H, H_2), 4.65 (m, 2H, H_5), 4.86 (q, 1H, H_4), 5.57 m, 1H, H_3), 6.48 (d, 1H, H_1), 7.25 (2d, 4H, aromatic-*H*), 7.95 (2d, 4H, aromatic-*H*). Anal. Calcd for $C_{21}H_{21}O_5Cl$: C, 64.86; H, 5.44. Found: C, 64.91; H, 5.62.

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